FUMIGATION OF CITRUS TREES

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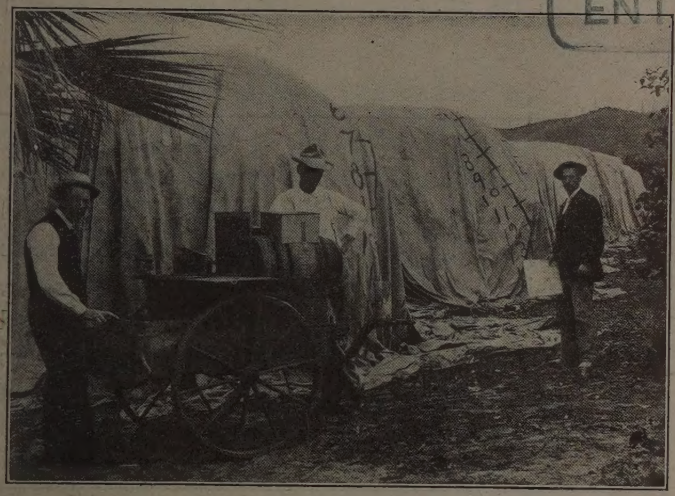

FARMERS' BULLETIN 923
UNITED STATES DEPARTMENT OF AGRICULTURE

Contribution from the Bureau of Entomology
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Washington, D. C. March, 1918

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WASHINGTON : GOVERNMENT PRINTING OFFICE : 1918

THIS bulletin contains a general account of the approved methods of fumigating citrus trees with hydrocyanic-acid gas to control scale insects and white flies. It deals with methods of procedure, necessary equipment, chemicals of fumigation, and effect of the gas on insects and plants, and includes dosage schedules to be employed for the control of the various common citrus pests.

FUMIGATION OF CITRUS TREES.[1]

CONTENTS.

	Page.		Page.
What citrus fumigation is	3	How to generate hydrocyanic-acid gas—Con.	
Equipment required in orchard treatment	4	The liquid hydrocyanic-acid method	16
Chemicals of fumigation	10	Fumigation procedure	16
How to generate hydrocyanic-acid gas	12	Effect of the gas on the plant	21
The pot method	12	Citrus insects and their control	28
The machine method	13	Cost of fumigation	30

WHAT CITRUS FUMIGATION IS.

THE FUMIGATION OF PLANTS with hydrocyanic-acid gas for the destruction of insect pests is one of the most important discoveries in the field of insect control. No other known gas so quickly destroys insect life and at the same time has so wide a range of usefulness. It was first used as an insecticide in 1886 by the late D. W. Coquillett, an agent of this department, for controlling certain scale insects on citrus trees in California. The immediate success and rapid development of the gas treatment in that State resulted in the almost complete abandonment of spraying as a means of controlling citrus scale insects, and led to the introduction of fumigation into other citrus regions of America, as well as into most of the important foreign citrus-producing countries.

The directions given in this bulletin are specifically for the control of scale and related insects infesting citrus trees, although, with proper modification, they will apply to the control of similar insects on other trees and plants.

Orchard fumigation for the control of citrus scale insects consists of covering trees with cloth tents, and liberating hydrocyanic-acid gas beneath these tents. The exposure of the insects to this gas for a definite period, varying with the insects to be controlled, will result in their destruction. In this connection the effect of the gas upon the plants, as well as upon the insects, must be considered.

[1] For a detailed report on fumigation in California see Bulletin 90 of the Bureau of Entomology, United States Department of Agriculture, published in 1911. This may be obtained for 20 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

CAUTION.—*Hydrocyanic-acid gas is colorless and is one of the most deadly poisonous gases known. It has an odor much like that of peach pits. In case of accidental inhalation of the gas, the person affected should be kept in the open air and required to walk to increase respiration.*

EQUIPMENT REQUIRED IN ORCHARD TREATMENT.

Orchard fumigation requires special equipment, comprising tents, poles for placing them over the trees, containers for the chemicals, and apparatus for generating the gas.

TENTS.

Flat cloth tents of octagonal design (fig. 1) are employed for orchard fumigation. To avoid waste of cloth in cutting, these tents are constructed of standard sizes based on the distance between parallel sides. The sizes commonly used are 36, 41, 43, 45, 48, 50, 52, 55, 64, 72, and 81 feet.

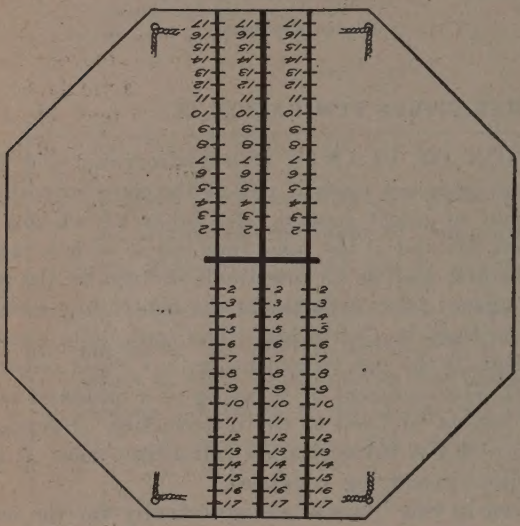

FIG. 1.—Fumigation tent marked according to the Morrill method.

In purchasing tents the orchardist should be guided by the size of the trees to be fumigated, making due allowance for their normal growth. Tents 36 or 41 feet in size should be used for citrus trees up to 10 feet in height; 41, 43, or 45 foot tents for trees 11 to 15 feet in height; 45, 48, or 52 foot tents for trees 16 to 20 feet in height; and 55, 64, or 72 foot tents for trees 21 to 25 feet in height.

The number of tents required depends largely upon the acreage of trees to be treated. In California the average commercial outfit contains from 25 to 60 tents. The usual length of exposure is one hour, and under the most favorable conditions one tent will cover 12 trees a night, though the average for the whole fumigation season approximates 8. One tent, therefore, should cover 90 trees (1 acre approximately) in 11 or 12 days, or 30 tents should cover 10 acres in 4 days.

MATERIAL.

Material for tents must be of the tightest possible weaves, comparatively light, and of sufficient strength to prevent tearing when trees are being covered. Heavy stiff tents are not only difficult to

manipulate but they break branches, injure fruit, and, moreover, will not fit closely to the ground around the trees, thus permitting rapid escape of the gas.

The materials now in general use for sheet tents are 6½-ounce and 7-ounce special drill, 8-ounce double-filled duck, and 7-ounce and 8-ounce special Army duck. A special, closely woven, 8-ounce United States Army duck is recommended as superior to any other cloth for fumigation tents, as it is strong and durable and retains the gas much better than the other grades of cloth.

CONSTRUCTION.

Experienced tent or awning makers are competent to construct these tents.[1] In fact, several firms in this country, particularly in California, specialize in their construction. To secure a tent actually the size required, due allowance must be made for shrinkage of new cloth. For example, a 43-foot tent of new cloth will shrink approximately 3 feet in length and half a foot in width after becoming wet, and other sizes will be reduced proportionately.

MARKING.

The prevalent system of fumigation requires special marking of the tents. Accurate marking is possible only after the cloth has been shrunk, which is easily accomplished by spreading the tents on a flat, open place where they can be saturated with water. Treatment for mildew, described later, also produces a shrinkage of the cloth. Untreated, factory-marked tents required due allowance for shrinkage.

A plan of marking tents that was devised by Dr. A. W. Morrill[2] is shown in figure 1. Three parallel lines running in the direction of the strips of cloth are graduated at intervals of 1 foot. The middle of each line is considered zero, and the numbering should be outward from this point. The distance between the parallel lines depends on the size of the tent. Three feet has been found to be an appropriate distance for tents up to 45 feet in size, and 4 or 5 feet in larger tents. The middle line should pass through the center of the tent. Where many tents are to be marked, a large stencil will facilitate the operation. The numerals should be at least 6 inches in height and can be made with printer's ink, lampblack and turpentine, or a soft, flexible, black paint.

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[1] A method of constructing fumigation tents is described in detail in Bulletin 90 of the Bureau of Entomology, United States Department of Agriculture.

[2] Morrill, A. W. Fumigation for the Citrus White Fly as Adapted to Florida Conditions. U. S. Dept. Agr. Bur. Ent. Bul. 76, p. 31. 1908.

MILDEW-PROOFING.

In a dry climate such as prevails in California tents are not usually treated to prevent mildew. Extensive handling resulting in acid burns and twig tears, rather than deterioration of cloth from mildew, is the chief reason for casting aside long-used tents in this State. In Florida, as well as in tropical countries where tents become wet every night, treatment to prevent mildew is necessary.

The dipping of tents in a solution of tannin to render them proof against mildew has been done for a long time and is very satisfactory. Tents are dipped in a vat containing the hot tannin solution (40 pounds extract of oak bark to about 100 gallons of water) for about 30 minutes, and then spread on the ground to dry. Contrary to the usual belief, the tannin treatment does not increase the gas-holding power of the tent, though it appears to increase its wearing quality. Tents also may be rendered mildew proof by permitting saturation in a hot solution of soap ($\frac{1}{4}$ pound to 1 gallon of water) and then digestion for 12 hours in a solution of alum ($\frac{1}{2}$ pound to 1 gallon of water). An excellent formula, which also waterproofs, consists of immersing canvas for 24 hours in a solution of 1 pound of soap to 50 gallons of water, after which the material is placed for 3 hours in a solution of 1 pound of alum and 1 pound of sugar of lead to 6 gallons of water. There are other satisfactory treatments which render canvas mildew proof, yet not stiff or heavy. Many tentmakers have special methods for mildew-proofing cloth.

GAS-PROOFING.

At present no satisfactory method has been found for gas-proofing tents without rendering their use impractical under the rough handling to which they are subjected in orchard fumigation.

HANDLING.

The life of a tent normally will range from three to five years, depending upon the extent of its use and the care accorded it, as well as the weather conditions to which it is subjected. In dry climates tents should last five or more years, provided they are handled carefully and well aired before storage. Wet tents should be spread out on the ground between the trees to permit the air and sun to reach them during the day. If very wet, they should be turned over once or twice, and in cool weather they should be pulled partly over a tree. At the close of the season tents should be dried thoroughly, rolled up, and stored in a dry room, *but never on a dirt floor.*

POLES AND DERRICKS.

Either two wooden poles or two derricks are used in placing tents over trees.

The lengths of poles commonly used are 14 feet and 16 feet. Eighteen-foot poles are needed occasionally for large trees. These poles average 2 to 3 inches in diameter, are rounded, and made of straight-grained, well-seasoned hard pine free from knots. In the Gulf Coast States seasoned cypress is a cheap and satisfactory material for poles. Cypress wood does not need to be milled, as the trees grow straight and slender. It is advisable to have an extra set of poles on hand in case one set is broken. The lower end should be sharpened slightly so that it will hold firmly in the ground, while the upper end, to which a rope is attached for the purpose of erecting the poles, should be narrowed bluntly or rounded in accordance with one of the methods suggested in figure 2. The ropes should be ½ or ⅝ inch and about 3 feet longer than the pole. A stout piece of rawhide is sometimes substituted for the first 3 feet of rope adjacent to the pole, as this section, being half hitched over the tent each time the pole is used (see fig. 10, p. 19), suffers the most wear.

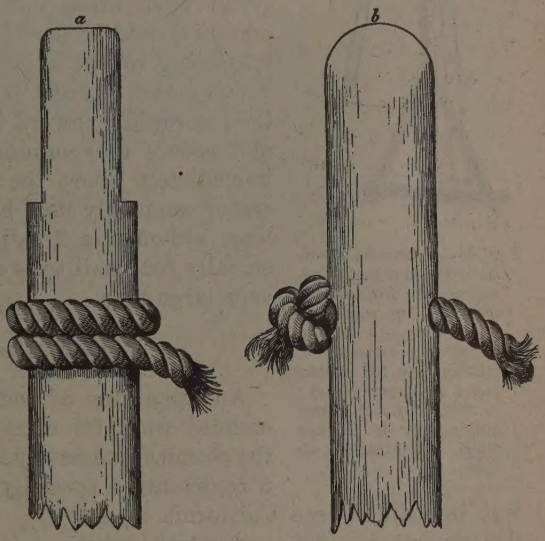


FIG. 2.—Ends of hoisting poles used in placing tents over trees: *a*, Used with tents where rings are present; *b*, used with tents having no rings.

In covering very tall trees it is necessary to use derricks with uprights about 3 feet higher than the tallest trees. Derricks usually are made of the same material as poles and have a framework attached to the bottom to prevent slipping and to confine the movement to one of two directions when the other end is raised. A rope and pulley arrangement is placed at the top for raising the tent, and the rope should be approximately three times the length of the pole. The uprights in common use average between 25 and 35 feet

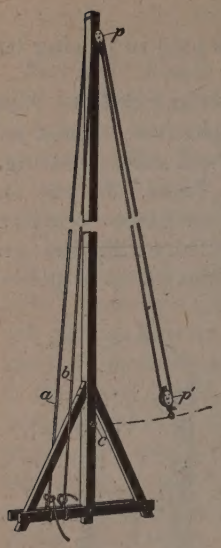


FIG. 3.—A derrick, showing rope and tackle arrangement for raising tents: *a*, Guy rope used in holding derrick in upright position; *b*, pulling rope for raising tent; *p*, upper pulley; *c*, ring to which lower pulley, *p'*, is hooked when not attached to tent.

in length, with the top 2½ to 3½ inches and the bottom 3½ to 4½ inches in diameter. The construction is shown in figure 3.

GENERATORS.

Under the pot system of fumigation, earthenware vessels, heavily glazed to prevent weakening by action of the acid, are required for generating hydrocyanic-acid gas under the tent. The type of vessel commonly used in California is shown in figure 4. Covers for generators should be used to prevent injury from spattering of the acid during gas evolution. These covers prevent tent burning, distribute the gas rapidly toward the bottom of the tree, and reduce to a minimum injury to foliage immediately above the generator. The generator commonly used holds from 1½ to 2 gallons, although a 1-gallon size is used occasionally for small trees and a 3-gallon size for very large trees.

CHEMICAL WAGONS.

An apparatus of some sort is required in orchard work for carrying from tree to tree the chemicals necessary in fumigation. Figure 5 represents a specially equipped cart which was introduced into California by this department in 1908 and which subsequently has gained wide usage. Such a cart can be drawn either by the men of the outfit or by a horse. Some fumigators prefer to use a horse-drawn wagon rather than a cart for carrying the chemicals, with the result that a number of very original and ingenious combinations have been devised.

FIG. 4.—A fumigation generator, with cover device.

OTHER EQUIPMENT.

Glass graduates of 16-ounce or 32-ounce size are used for measuring acid and water. Other necessary apparatus includes rubber gloves, cyanid scoop, lantern or torch with supply of kerosene, large earthenware

pitcher for holding acid before it is poured into the acid jar, lead or copper funnel, large water pail, two to four 10-gallon glass acid carboys in stout wooden frames with handles, a covered tin-lined box large enough to hold 200 pounds of cyanid, barrels for water, thermometer, hygrometer, 75-foot tape line, and schedule cards of fumigation dosages.

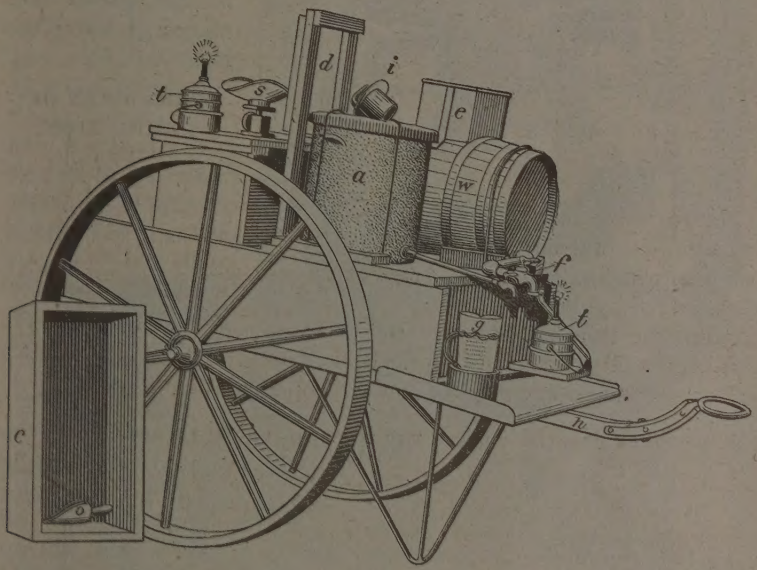


FIG. 5.—Supply cart for carrying chemicals: *a*, Acid jar; *i*, cover fitting into opening of acid jar; *w*, water keg; *e*, funnel for pouring water into keg; *f*, faucets for drawing water and acid; *s*, cyanid scales; *d*, schedule board; *t*, *t*, torches; *g*, graduate; *c*, cyanid box; *o*, cyanid scoop; *h*, cart handle.

FUMIGATION MACHINES.

A fumigating machine that has been in use in California (fig. 6) consists of a large generating drum mounted on two wheels and provided with shafts. Above the generating drum are two tanks, one for cyanid solution and the other for sulphuric acid. The liquid from each of these tanks is conducted to a measuring cylinder, from which it flows through a cut-off valve into a tray suspended within the large generating drum. The resulting gas passes from the generator to the tent through a large hose, while the residue remains on the bottom of the drum.

Another fumigation machine used in California (fig. 7) consists of two tanks, one above the other, the lower containing a mixture of equal parts of sulphuric acid and water, while the upper contains the cyanid solution. By the action of a suitable pump measured quantities of the

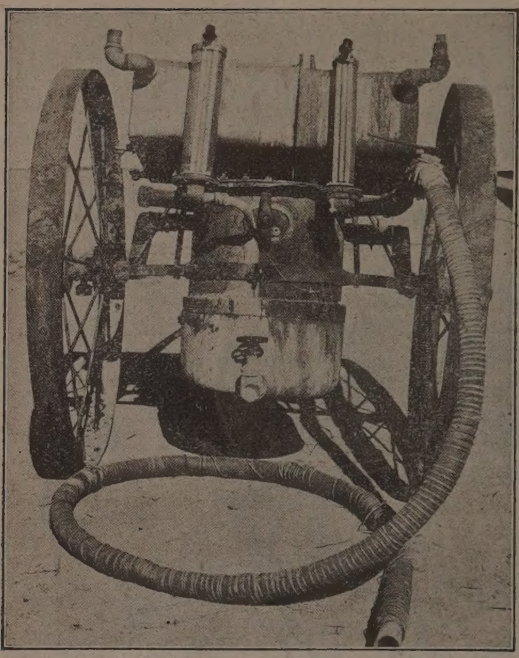


FIG. 6.—A fumigating machine that has been in use in California.

cyanid solution are forced into the tank containing the acid-water mixture, and the gas instantly generated escapes to the tented tree through a large hose.

CHEMICALS OF FUMIGATION.

Cyanid of sodium or cyanid of potassium, sulphuric acid, and water are necessary for the generation of hydrocyanic-acid gas.

CYANID.[1]

Either sodium cyanid or potassium cyanid, in the crystal form, can be used in fumigation. Potassium cyanid was used exclusively up to 1909, but since that date has been superseded by sodium cyanid.[2] Considering the world's limited supply of available potassium salts, there is little likelihood that potassium cyanid will be used again extensively in orchard fumigation.

Sodium cyanid for fumigation purposes should be of 96 to 99 per cent guaranteed purity, thus containing not less than 51.3 per cent of cyanogen. The volume of gas liberated is governed directly by the purity of the cyanid. The dosages for different insects are based on pure cyanid, and poor results are likely to follow if impure chemicals are used. *Too much stress can not be placed on the importance of purchasing high-grade cyanid*, in view of the fact that much of this material on sale by retail druggists is very impure, and thus unsuited for fumigation.

The purchaser will be protected if he obtains a cyanid guaranteed under the Insecticide Act. The analysis on the label should indicate that the cyanid is at least as pure as the following:

[1] All recommendations made in this bulletin are for sodium cyanid 96 to 99 per cent pure. For the use of potassium cyanid see Bulletin 90 of the Bureau of Entomology, United States Department of Agriculture.

[2] See Bulletin 90, Part 2, of the Bureau of Entomology, page 83.

SODIUM CYANID (NaCN), 96 TO 99 PER CENT.

Analysis.

		Per cent.
Cyanogen (CN)	not less than	51.3
Sodium (Na)	not less than	43.7
Inert substances	not over	4.0
Chlorids	not over	1.4

Cyanid is decomposed by the action of moisture, and should be protected from dampness by storage in a tightly covered tin box. If a box of cyanid is to stand for several days without being used, fill the empty space with old cloth or burlap to prevent exposure of the cyanid to air. Unused cyanid at the end of the season's work should be placed in as small a tin as possible and tightly sealed. High-grade cyanid for chemical use can be purchased in cases of 50, 100, or 200 pound sizes.

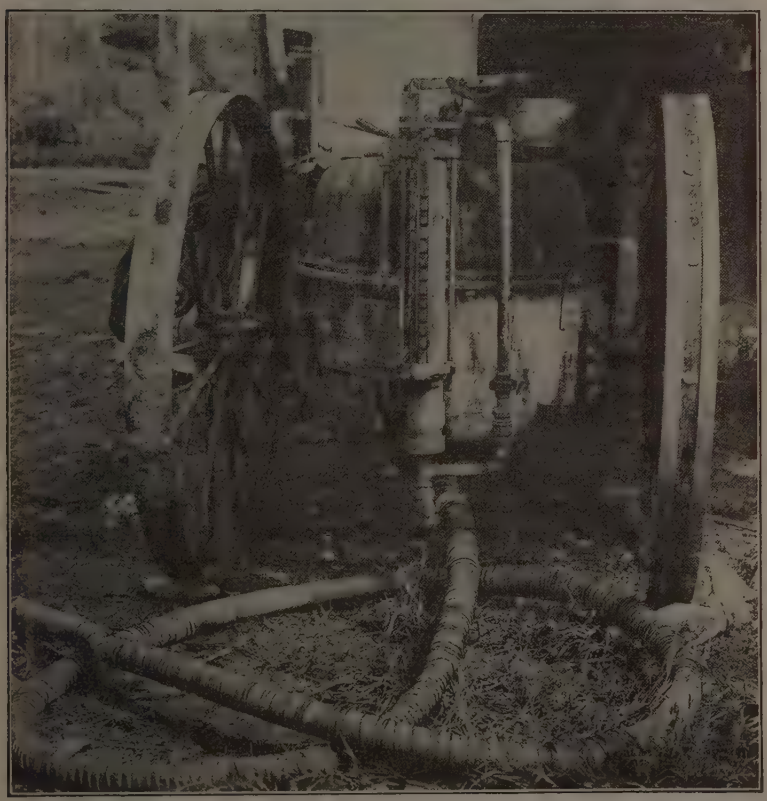


FIG. 7.—A fumigating machine used in California.

SULPHURIC ACID.

A commercial sulphuric acid (H_2SO_4) 92 to 94 per cent pure (66 degrees Baumé), free from nitric acid, arsenic, lead, and zinc, should be used. It does not matter whether the acid is made from pyrites or from pure brimstone, provided all impurities are eliminated. Acid is usually purchased in large iron drums holding from 1,500 to 2,000 pounds. It can be purchased also in glass carboys of about 10 gallons capacity. Pure acid is colorless and about twice as heavy as water, its specific gravity being 1.83. If stored in iron drums it frequently has a slightly milky color, especially toward the bottom of the drum. This color is due to sulphate of iron, produced by acid coming in contact with iron either before or after the acid is placed in the drum. This sediment in no way affects the value of the acid, unless it is present in excessive quantities.

Acid may be removed from drums in the field, although it is preferable to convey it thither in 10-gallon glass carboys. Acid will burn the flesh or destroy the clothing quickly, and care should be observed in its handling. Should acid come in contact with the flesh, wash the affected parts quickly with water. The use of rubber gloves in handling the acid containers is advisable.

HOW TO GENERATE HYDROCYANIC-ACID GAS.

THE POT METHOD.

Fumigation with hydrocyanic-acid gas was developed to its present stage of efficiency under the pot method, the gas being generated in a vessel under a tent by combining cyanid, sulphuric acid, and water in a glazed earthenware vessel. For each ounce, by weight, of sodium cyanid 1½ ounces, liquid measure, of sulphuric acid and 2 ounces of water are required to evolve the maximum volume of gas and carry the reaction to completion. This is known as the 1–1½–2 formula. This gives satisfactory results under field conditions, although some fumigators prefer to use 1¼ ounces of sulphuric acid to each ounce of sodium cyanid. For large dosages the latter formula appears quite satisfactory, but in the case of small dosages undissolved cyanid frequently remains and is a cause of complaint.

MIXING THE CHEMICALS.

In mixing the chemicals the water should be measured first and poured into the generator. Next, the acid should be measured and added to the water. This acid-water solution will become very hot. Then the generator should be placed at once beneath the tented tree, and the required amount of cyanid added. The operator can avoid contact with the hydrocyanic-acid gas, which is liberated immediately,

by placing the cyanid into the acid-water solution at arm's length. The foregoing procedure should be adhered to closely. *Acid must not be poured into a cyanid-water mixture, as a violent reaction will result.*

The acid-water mixture never should be allowed to cool before the cyanid is added, as a heated solution is necessary for a complete generation of gas. The cyanid should be in lumps averaging about the size of an English walnut, and small pieces should be used only in small dosages. A charge composed entirely of powdered cyanid results in a violent reaction, which is dangerous.

SMALL DOSAGES.

In field fumigation generators of the same size are used frequently with both small and large dosages. In general the results from dosages not exceeding 3 ounces of cyanid are less satisfactory than those from larger dosages, since with the former there is often an incomplete generation of the gas. For the best possible generation there must be enough liquid in the generating vessel to cover the cyanid completely. This is not always accomplished by following the recommended formula with 1-ounce to 3-ounce dosages in flat-bottomed jars unless the cyanid used is in very small pieces and the jar is placed on edge.

Extensive research in chemistry has shown that an extra ounce of acid and 2 extra ounces of water added to the quantity required by the formula will give the needed amount of liquid and will in no way affect the liberation of gas in 1, 2, and 3 ounce dosages.

NATURE OF THE RESIDUE.

The residue from the generation of hydrocyanic-acid gas is very poisonous and usually is in the form of a bluish or greenish colored liquid consisting of water, sulphate of sodium, sulphuric acid, and hydrocyanic acid. Vegetation, such as cover crops, is destroyed by the action of this residue, and even surface roots of citrus trees in loose sandy soil are likely to be injured severely.

Some orchardists demand that the residue be carried off the field, but this precaution is unnecessary in ordinary fumigation where small dosages are used. The residue should never be emptied near the base of a tree, however, but midway between two rows previously fumigated. Care should be exercised that the tents do not come in contact with the residue.

THE MACHINE METHOD.

Recent developments in orchard fumigation have eliminated, to a large extent, the use of earthenware pots through the introduction of portable machines for generating the gas outside of the fumigating

tent. This development is especially interesting in that it is a return to the principle of generation followed by the late D. W. Coquillett in 1886, when he discovered the efficacy of hydrocyanic-acid gas in the control of insect pests of citrus trees. Mr. Coquillett's procedure consisted in bringing the cyanid dissolved in water in contact with sulphuric acid in a vessel outside the tent, and conducting the resulting gas under the tent by means of a pipe. In 1889 this procedure gave way to the pot method described in foregoing pages.

The first fumigating machine (fig. 6) was introduced in 1912, and the other (fig. 7), which differs in important features from the former, in 1915. These machines were used very extensively during 1915, 1916, and 1917.

GENERATING THE GAS.

The cyanid solution used in both machines is made of high-grade sodium cyanid dissolved in water at the rate of 1 ounce of cyanid to 2 fluid ounces of water. The dissolved cyanid increases the volume of the solution approximately 25 per cent, and this increase must be considered in graduating the cyanid-measuring apparatus. Undiluted commercial sulphuric acid in measured quantities at the rate of 1¼ ounces of acid to each 2½ ounces of cyanid solution, is used in the machine shown in figure 6. The machine shown in figure 7 differs in principle from that shown in figure 6 in that small amounts of cyanid solution are added successively to a large amount of dilute sulphuric acid until the latter is nearly exhausted.

THE INITIAL DOSE.

The generating cylinder of a fumigation machine, before starting work, contains a large amount of air which must be displaced before the full charge of cyanid gas is available. Mr. H. D. Young, of the University of California, states that two charges are required to expel all the air, and recommends that 4 ounces of cyanid be added to the first charge and 2 ounces to the second to meet this condition. Examination of small trees fumigated by operators who used no additional material with the first charges has shown much poorer results on the first row than on the succeeding ones.

DISSOLVING THE CYANID.

A heavy sheet-steel or sheet-iron tank is used for dissolving cyanid, which should be suspended near the top of the tank, as cyanid in solution is heavier than water. The cyanid purchased in 200-pound containers is dissolved readily by cutting numerous slashes along the lower edge and in the bottom and then suspending it in a tank con-

taining 50 gallons of water. Cyanid solution deteriorates materially when exposed to direct sunlight, but when it is kept covered in a cool place no deterioration takes place if allowed to stand from a week to 10 days. Before the machines are loaded cyanid solution should be stirred thoroughly to insure uniformity. Determinations made by the Bureau of Chemistry of this department show that cyanid solution of the concentration of 1 ounce of commercial sodium cyanid to 2 ounces of water will crystallize at a temperature approximating 40° F.; in fact, one instance of crystallization at a low temperature in commercial work was observed in December, 1915. It would appear inadvisable, therefore, to use a cyanid solution at a temperature below that at which crystallization takes place.

RESULTS WITH MACHINE FUMIGATION.

Horticultural commissioners, fumigators, and orchardists largely agree that the general results in scale-insect destruction are as satisfactory with the machine method as with the pot system. An investigation of gas generation with the machine shown in figure 7 showed that the average yield of gas with this machine approximates the amount evolved in pot generation.[1] It has been assumed that the amount of gas generated in the machine shown in figure 6 approximates that evolved by the pot method, since the proportion of chemicals used is the same in both cases. Although no investigation of the gas yield of this machine has been published, results reported in field work appear to corroborate this assumption. The most serious drawback of this machine appears to have been its defective construction. Nonuniformity of results in certain orchards fumigated with the machine shown in figure 7 was reported in November, 1915, by Dr. A. G. Smith, horticultural inspector for Pasadena, Cal. A careful inspection of several groves showed that the results in the destruction of scales were decidedly inferior on the last few trees in each row treated. The addition of extra acid to the machine toward the end of each row is reported to have remedied this. That the commercial success of machine generation is assured is shown by the fact that the major part of citrus fumigation in California during the last season (1917) was performed under the machine method.

DOSAGE.

The same dosage schedules are used with machines as with pots (see pp. 17 and 18), and all general recommendations for procedure, avoidance of plant injury, and insect control are applicable for both pot and machine generation.

[1] University of California Agricultural Experiment Station Circular 139. 1915.

ADVANTAGES OF MACHINE GENERATION AS COMPARED WITH POT GENERATION.

The two principal advantages of the fumigating machines are the lessened amount of tent burning and the greater accuracy possible in measuring the chemicals. One man less is required on an outfit, pots are no longer necessary, and the chemicals of fumigation are handled more economically. Carrying the residue from the field eliminates possible tree and tent injury from this source, while the danger of poisoning or burning the operator is reduced greatly by the less direct handling of the chemicals. The rapid generation of gas allows a greater initial concentration than by the pot method, and tends toward greater effectiveness. Handling a machine is less strenuous to the operator. Considering all these advantages it is apparent that the generating machine now forms a permanent part of the equipment for orchard fumigation. The pot method is doubtless more economical and practical for the private owner who has only a few trees to be treated, and for the fumigation of house-lot trees and trees in terraced orchards inaccessible to a machine.

THE LIQUID HYDROCYANIC-ACID METHOD.

The value of liquid hydrocyanic acid for the control of citrus pests was first demonstrated to the orchardists of California in 1916 and since then has gained a limited adoption. Some very satisfactory results have been obtained and this method, after standardization, gives promise of wide usage in the control of insect pests infesting citrus trees.

Liquid hydrocyanic acid is condensed from the gas and is transported in iron drums to the groves. The method of application is extremely simple. Liquid hydrocyanic acid is carried in a small tank which is mounted on a platform with a pump. The liquid is first measured, drawn into the pump, and finally discharged through a small pipe fitted with a spray nozzle. Simplicity of handling, which does away with the necessity of bringing cyanid and sulphuric acid into the field, and the elimination of tent burning are advantages in favor of the new method.

FUMIGATION PROCEDURE.

DOSAGE SCHEDULES.[1]

The term "dosage" is used to indicate the amount of cyanid needed to destroy a particular insect, and varies with the size of the

[1] In previous writings the author has referred to high-grade sodium cyanid as being 126 to 130 per cent pure. An equal amount by weight of chemically pure sodium cyanid liberates 33 per cent more hydrocyanic-acid gas than does pure potassium cyanid; and as potassium cyanid was the chemical formerly used for generating hydrocyanic-acid gas, this was expressed by designating the pure sodium cyanid as 133 per cent. In this bulletin where sodium cyanid is mentioned as 96 to 99 per cent pure, or containing not less than 51.3 per cent of cyanogen, it is of the same strength as that termed in former writings "126 to 130 per cent pure." Likewise dosage schedule 1 for sodium cyanid 96 to 99 per cent pure, containing not less than 51.3 per cent of cyanogen, is the same schedule as that formerly termed "dosage schedule 1" for sodium cyanid 126 to 130 per cent pure.

tree. Since a definite amount of gas is generated from an ounce of cyanid, the dosage is indicated in ounces.

Several years of experimental work in California, during which thousands of trees have been treated for the control of different scale insects, have made it possible to calculate dosages for different-sized trees and to prepare tables in convenient form for rapid use in the field. (See fig. 8.) These dosages are based on actual results under practical field conditions, proper consideration being given to the important subject of leakage.

The dosage for a tree is determined by two measurements taken after the tree is covered with a tent. These are the distance in feet around the tent at a height of about 3 feet from the ground and the distance in feet over the top of the tent from ground to ground. The numbers indicating the size of the tree are arranged along the outer sides of the chart. The square in the chart, formed by the intersection of the lines running from the two numbers representing, respectively, the distance around and the distance over a tree, contains the dosage for a tree of this size. For example, if it is found that the distance over the tent is 30 feet and the distance around the tent is 42 feet, the intersection of the lines leading from these numbers indicates that 10 ounces of sodium cyanid is the amount required by a tree of that size with dosage schedule No. 1 (see fig. 8). Using

DISTANCE AROUND, IN FEET.

DISTANCE OVER, IN FEET.	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	
10	2	2	2	2	2																							10
12	2	2	3	3	3	3																						12
14	3	3	3	3	3	3	4	4	4	4	4	5																14
16	3	3	3	3	4	4	4	4	4	5	5	5	5	5														16
18	3	3	3	4	4	4	5	5	5	5	5	5	5	6														18
			20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	30	52	54	56	58	60	62	64	66	68	
20			3	4	4	5	5	5	5	5	5	6	6	6	7	7	8	8										20
22					5	5	5	5	5	5	6	6	7	7	8	8	8	8										22
24						5	5	5	6	6	6	7	8	8	8	8	9	9										24
26							5	6	6	7	7	8	8	8	9	9	10	10	10	11	11	11						26
28								6	7	8	8	8	8	9	9	10	11	11	11	11	12	12						28
								30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	
30								7	8	8	8	9	9	10	10	11	11	11	11	12	13	14	14	14	15	16	16	30
32											9	10	10	11	11	12	12	12	13	13	14	14	14	15	16	16	17	32
34												10	11	11	12	13	13	14	14	14	14	15	16	16	17	17	17	34
36												11	11	12	13	13	14	14	15	15	16	17	17	17	17	18	19	36
38													12	12	13	14	14	15	15	16	17	17	17	18	18	19	20	38
													40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	
40													12	13	14	14	15	15	16	17	17	18	18	19	20	20	20	40
41														14	14	15	15	16	17	17	18	18	19	20	20	20	21	41
42															15	15	16	17	17	18	19	19	20	20	20	21	21	42
43																16	17	17	17	19	19	20	20	20	20	21	22	43
44																		17	17	19	20	20	20	20	21	22	22	44
																		50	52	54	56	58	60	62	64	66	68	
45																		17	19	20	20	20	20	21	22	23	23	45
46																		18	20	20	20	20	21	22	22	23	23	46
47																		18	20	20	20	21	22	22	23	23	24	47
48																		19	20	20	21	22	22	23	23	24	24	48
49																		19	20	21	21	22	23	23	23	24	25	49

FIG. 8.—Dosage schedule No. 1, for sodium cyanid 96–99 per cent (containing not less than 51.3 per cent cyanogen). Dosages are in ounces.

the 1–1½–2 formula for sodium cyanid, 15 ounces of sulphuric acid and 20 ounces of water would be required for this charge.

Experience has proved that for the most part citrus scale-insect pests do not require as strong a dosage for their destruction as is given in schedule No. 1. A schedule of dosages (fig. 9) three-fourths as strong as those in schedule No. 1 has, therefore, a broader usage. Weaker schedules, as one-half, one-third, etc., can be prepared if needed.

HOW TO MEASURE THE TREES.

As was stated in the preceding section, the dosage for a tented tree is based on the distance over the top and the distance around the bottom. The distance over the top of a tree is measured easily with a tapeline, but a much better and quicker method is to mark the tent as described previously. When such a marked tent is centered over a tree, the distance over the top is obtained by adding the two numbers that show where the line over the top of the tree touches the ground on opposite sides.

In tenting trees, especially small ones, the center of the tent frequently will fall to one side of the center of the tree, and in such instances one of the auxiliary lines is used. To avoid confusion, the center line should be heavier than the other two. The distance around the tent is taken by means of a tapeline, and can be measured by one man if the tape be provided with a catch for attachment to

DISTANCE AROUND, IN FEET.

DISTANCE OVER, IN FEET

	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	
10	2	2	2	2	2																							10
12	2	2	3	3	3	3																						12
14	3	3	3	3	3	3	3	3	3	3	3	4																14
16	3	3	3	3	3	3	3	3	3	4	4	4	4	4														16
18	3	3	3	3	3	3	4	4	4	4	4	4	4	5														18
			20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	
20			3	3	3	4	4	4	4	4	4	5	5	5	5	5	6	6										20
22					4	4	4	4	4	4	5	5	5	5	6	6	6	6										22
24						4	4	4	5	5	5	5	6	6	6	6	7	7										24
26							4	5	5	5	5	6	6	6	6	7	8	8	8	8	8	8						26
28								5	5	6	6	6	6	7	7	8	8	8	8	8	9	9						28
								30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	
30								5	6	6	6	7	7	8	8	8	8	8	8	9	10	11	11	11	11	12	12	30
32											7	8	8	8	8	9	9	9	10	10	11	11	11	11	12	12	13	32
34												8	8	8	9	10	10	11	11	11	11	11	12	12	13	13	13	34
36												8	8	9	10	10	11	11	11	12	13	13	13	13	14	14		36
38													9	9	10	11	11	11	12	12	13	13	13	14	14	14	15	38
													40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	
40													9	10	11	11	11	11	12	13	13	14	14	14	15	15	15	40
41														11	11	11	11	12	13	13	14	14	14	15	15	15	16	41
42															11	11	12	13	13	14	14	14	15	15	15	16	16	42
43																12	13	13	14	14	14	15	15	15	15	16	17	43
44																		13	14	14	14	15	15	15	16	17	17	44
																		50	52	54	56	58	60	62	64	66	68	
45																		13	14	14	15	15	15	16	17	17	17	45
46																		14	14	15	15	15	16	17	17	17	17	46
47																		14	14	15	15	16	17	17	17	17	18	47
48																		14	15	15	16	17	17	17	17	18	18	48
49																		14	15	16	16	17	17	17	17	18	19	49

Fig. 9.—Dosage schedule No. 3/4, for sodium cyanid 96–99 per cent (containing not less than 51.3 per cent cyanogen). Dosages are in ounces.

the tent. This measurement should be taken about 3 feet above the ground. *Never guess the distance around by pacing.*

HOW TO COVER THE TREES.

Commercial fumigators usually require that the soil in the orchard shall have been cultivated recently, so that it will be loose and level before the work of fumigation is begun, thus permitting the tents to lie smooth and close to the ground. One tent is then spread on the ground on the side of each tree, in the first row to be treated, farthest from the center of the orchard.

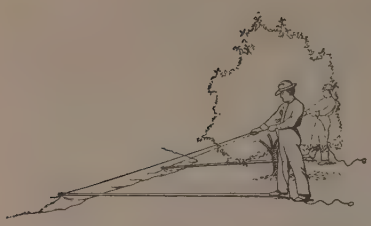
For covering trees up to 18 or 20 feet in height, two poles of the character described on page 7 are required, one for each side of the tree. Preferably the poles should be about a foot longer than the height of the trees. If rings are attached to the tents the ends of the poles are inserted into the rings. It is very much easier, however, not to use rings on tents manipulated by poles, but to double-lap the edge of the tent over the end of the pole and attach it by a half hitch of the pulling rope. (Fig. 10.) This is done quickly, does not subject the tent to undue wear, prevents detachment, which sometimes occurs with rings, and allows the distance between the poles to be varied in accordance with the width of the tree. *To prevent the seams from pulling apart, the tent always should be moved in the direction in which the strips run.*

FIG. 10.—Method of attaching tent to hoisting pole by a half hitch of the rope.

The successive stages in covering a tree are shown in figures 11 to 14. The tent should be held taut between the ends of the poles to prevent it from catching in the top of the tree by sagging. When the covering is completed the poles are detached and carried to the next tree to be covered.

Great care should be exercised in covering large trees to avoid overpulling the tent. The bottom of the tent should be kicked in and, at the same time, examined to see that it lies close to the ground the entire distance around the tree. Where possible, it is much easier to transfer a tent from tree to tree without pulling it to the ground. The poles should be attached to the edge of the tent, then raised and leaned against the tented tree. The remaining steps are the same as those previously explained.

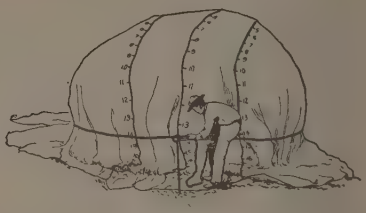
To cover very large trees derricks such as are described on pages 7 and 8 should be used. Four men are required for their manipulation. (See figs. 15–17.)



11.

12.

13.



14.

FIGS. 11–14.—Successive stages in placing a tent over a tree with poles.

OPERATION OF AN OUTFIT.

To operate a set of 30 tents to advantage under the pot system five men are required; two to pull the tents and kick in the edges, one to take the measurements and determine the dosage, and two to measure the chemicals and dose the trees. Under the machine method only one man is required to handle the chemicals. Care should be taken that the pots are placed well inward from the tent, so that any spattering of acid during the generation of gas will not reach the cloth. The man handling the acid should never touch the tents.

Outfits employing 40 to 60 tents usually employ six or seven men. In this case four men are employed as tent pullers and the others as previously explained.

CARE OF TENTS.

One of the greatest necessities, and at the same time the one most likely to escape notice, is the proper repairing of fumigation tents. If acid comes in contact with a tent, a hole is certain to be the result, and even with very careful operators acid holes are occurring constantly. These become very numerous if not attended to, and permit leakage of gas. Moreover, tears in tents are of frequent occurrence.

Every large outfit should employ a man whose sole duty is to overhaul tents and keep them in the best possible state of repair. This man should be supplied with a sewing machine adapted to tent

mending. Tents are best patched by sewing pieces of canvas over the holes, rather than by trying to draw holes together with threads. Patches stuck by rubber tissue are temporarily satisfactory, but are not lasting, and for this reason are inferior to those machine-sewed. In the daytime tents should be spread out to dry.

NECESSITY FOR CAREFUL WORKERS.

Unsatisfactory fumigation is frequently the direct result of carelessness, and for fumigating an orchard it is of primary importance to have careful, conscientious men. It is very easy for a careless scheduler to form the habit of guessing rather than measuring the dosages of trees, for the careless man with the supply wagon to make unnecessary mistakes in weighing the chemicals, and for the tent pullers not to kick in the skirts of the tent or pull down the sides which do not touch the ground. Carelessness or neglect in any one of these particulars will influence the results unfavorably.

Since fumigation is carried on only at night and for a short season, it frequently is difficult to secure desirable labor. Experience has proved that the best work is done where regular employees are transferred temporarily from other duties to assist in fumigation, and for this reason the orchardist, if possible, should have his field employees fumigate his trees. Citrus associations possessing outfits should transfer careful men from their packing houses or field crews.

Where there are several fumigation outfits operating in a community, it is urged strongly that a competent, well-trained man be employed at a regular salary to have personal charge of all control work with insecticides.

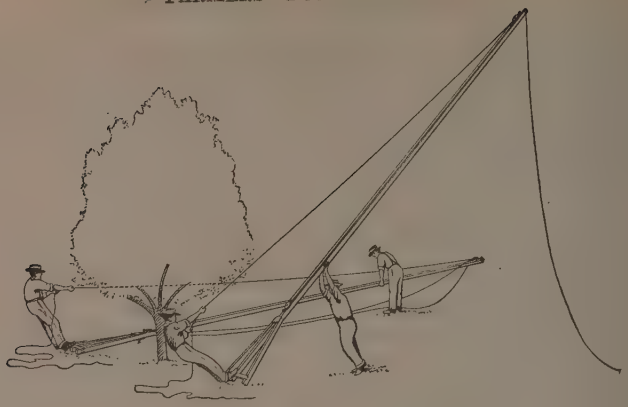
GENERAL CAUTIONS.

Hydrocyanic-acid gas is one of the most deadly gases known. Therefore precautions in its use are essential. The careful fumigator who avoids being subjected to strong fumes, however, runs no risk. In California men work around tented trees where they breathe diluted gas every night for several consecutive weeks without feeling any ill effects aside from an occasional dizziness or headache. Cyanid should be kept in containers tightly locked while not in use.

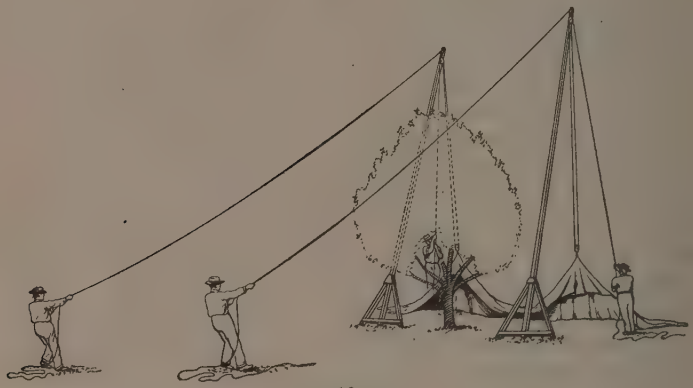
Hydrocyanic-acid gas is inflammable, and care should be exercised not to permit the concentrated gas as it rises from the generator to come in contact with fire; diluted gas is not inflammable.

EFFECT OF THE GAS ON THE PLANT.

Hydrocyanic-acid gas is fatal to insects when the dose is sufficiently large and the exposure long enough, but a much greater strength of gas is necessary for the destruction of some insects than for others. Were it not for the destructive action of the gas on the plants, its field of usefulness would be increased greatly. Since different species



15.



16.

17.

FIGS. 15–17.—Successive stages in placing a tent over a tree by means of derricks.

and varieties of plants vary remarkably in their power to withstand the poison, however, it is necessary in fumigating with this gas to take into consideration the particular plants to be fumigated and their susceptibility to gas injury.

The foliage and branches of orange, lemon, and grapefruit trees will stand without severe injury a strength of gas sufficient to destroy most of the scale insects which infest them. Apple, peach, pear, and other deciduous trees in dormant condition can be fumigated without injury with a strength of gas greater than it would be advisable to use on citrus fruit trees.

It is impossible to fumigate a citrus tree effectively without burning back for a few inches many of the tenderest shoots. Slight burning of the foliage, however, is not considered injurious to the trees. The injury to be avoided is the burning and pitting of fruit, and this frequently occurs unless great care is exercised.

The action of hydrocyanic-acid gas on the plant cells is the cause of fruit burning as well as foliage injury in fumigation. Numerous factors, explained later, serve to intensify the injury, but these factors are distinct from the main cause.

The tenderest shoots of plants are the ones most easily injured by this gas. It is well known that a very heavy dosage in field fumigation will not only pit full-grown fruit, but even destroy the old resistant foliage. Plants in dormant condition are more resistant to gas than are those in their period of growth. When fruit is small and tender it is easily pitted by a moderate strength of gas, whereas the same concentration applied when the fruit has matured may produce no injury at all. The epidermis and the cells immediately beneath in immature fruit seem to be much more susceptible to injury from gas penetration than those in mature fruit.

GAS INJURY THROUGH ABRASION OR PUNCTURING OF THE SKIN OF FRUIT.

It is of common occurrence to see injured fruit in the very tops of fumigated trees. When both tents and fruit are dry severe injury is infrequent, but should either or both become very wet severe injury might follow. Especially is this true after fumigation in damp weather on loose, sandy soil. Damp tents collect sand and, when drawn over the trees, scrape the fruit, causing abrasions of the epidermis. Once the epidermis is abrased and the cells beneath exposed, the absorption of the gas apparently intensifies the injury, which spreads and usually results in the collapse of a considerable area of skin. These spots are called pits or burns and do not show for from one to three days after fumigation.

Where trees are fumigated under ideal conditions and some fruit is pitted, a close inspection will reveal that many of these pits are in

places where the fruit has been abrased by contact with tents, poles, branches of the tree, or other fruit. If the poles are placed well in toward the tree so that they scrape or throw about branches or fruit in covering, abrased fruit sometimes results, especially in damp weather. The tents weigh down the branches and move them more or less severely during the covering of a tree. Where fruit comes sharply in contact with the ragged edge of a branch abrasion of skin is likely to follow. A heavy wind which beats the branches about will also cause much abrasion. Moist weather intensifies this condition. Sometimes, in separating fruit on a cluster after fumigation, pits are found at points of contact. This might be due to weakness of the epidermis, the result of one fruit brushing against another, or insect attack, which is frequently localized in such protected places. In certain cases insects which frequent citrus trees unquestionably play an important part in pitting. Fruit injured by fumigation has been seen which, at the time of treatment, was severely infested with mites, or red spiders.

Unless the skin has been abrased or weakened shortly before the treatment, well-grown fruit on healthy citrus trees is seldom injured by the average dosage applied under proper weather conditions.

CONDITIONS OF WEATHER DURING WHICH GAS INJURY IS LIKELY TO RESULT.

Unfavorable weather conditions at the time of fumigation are often responsible for injury to trees and fruit. In the following paragraphs various meteorological elements are discussed briefly.

LIGHT.

Fumigation should be carried on only at night. By careful treatment in cool, cloudy weather it is possible to fumigate trees in the daytime without serious injury, provided the dose is weak, but this practice is not followed in this country. Long periods of cool, cloudy days seldom occur during the regular fumigation season, and past attempts by some fumigators to practice daylight fumigation generally have resulted in such severe injury that the practice has been rightly discontinued.

The actinic rays of light intensify plant injury, both during and immediately after fumigation. Plants fumigated in direct sunshine, or placed in direct sunshine within one or two hours after treatment, usually are injured, the degree of injury depending upon the strength of gas used and the temperature of the air. Plants fumigated in diffused light appear to be no more injured than those fumigated in darkness.

Trees of the first row fumigated at night and those of the last row fumigated in the morning frequently are more or less injured. In the former case the injury is due to the fact that operations were

begun before the sun had set; in the latter case, to the fact that the operations were continued after sunrise. The injury described above is more apparent in the summer than in the cool days of late autumn.

TEMPERATURE.

Heat.—Heat apparently increases the poisonous properties of hydrocyanic-acid gas, and instances of severe injury directly attributable to high temperatures have occurred during commercial fumigation. Very little injury results from heat alone at a temperature as high as 70° Fahrenheit with the use of schedule No. 1, but *it is well to hold this temperature as a maximum* unless the orchardist is willing to assume risks. Where much weaker dosages are used, it is possible to fumigate at a higher temperature without severe injury, though the risk is great. In a case such as that of the citricola scale, an insect susceptible to fumigation only in its immature stages, which occur during the hot summer months, it frequently is advisable to treat even at temperatures in excess of the degree of perfect safety.

Cold.—Experience has shown that fumigating trees at a temperature near the freezing point often results in severe injury. In some instances treatment has been carried on with impunity at a freezing temperature, where light dosages were used, but the risk is too great to justify such treatment of citrus fruit trees. It is recommended that fumigation be discontinued when the temperature drops to 38° Fahrenheit.

WINDS.

Fumigation should never be attempted during a heavy wind for two reasons: First, the gas is blown out of the tent, so that poor work results; second, injury to trees may occur. The burning of fruit during heavy winds has been observed frequently. It has been explained previously that hydrocyanic-acid gas in contact with skin abrasions of citrus fruits usually produces pits, and this is undoubtedly the explanation of fruit injury while fumigating during heavy winds which beat about the tents and fruit-laden branches, thereby abrasing the fruit while exposed to the gas. A safe guide to follow is to discontinue fumigation as soon as the wind is sufficiently strong to cause the tents to flap. In California there are winds called locally "Santa Ana," or "electric," which are the result of storms in the surrounding desert, and fumigation during these periods is especially to be avoided, as they are accompanied usually by high temperatures.

MOISTURE.

Although hydrocyanic-acid gas in the presence of water readily passes into solution, it has been proved definitely that the presence

of water alone on citrus trees is in no way responsible for burning by possible absorption of gas.

There are other reasons of an indirect and largely mechanical nature, however, which necessitate the consideration of moisture. (1) The presence of moisture increases the weight of the tents, rendering them more difficult to handle, which results in much injury to fruit and branches. (2) On light, sandy soil, damp tents collect much dirt and injure fruit by scraping when being pulled over trees. (3) Moisture affects the fiber of the cloth, rendering it more impervious to gas. Therefore in fumigating large trees on a damp night more gas accumulates in the tops of the tents than is normally the case. This intense strength of gas sometimes causes pitting, especially with varieties least resistant to hydrocyanic-acid gas.

Doubtless the chief cause of fruit injury is the action of hydrocyanic-acid gas on skin abrasions produced by covering the tree with wet, heavy tents. Entire rows of trees have been seen in which fully half of the fruit had been rendered worthless from severe gas burning at tent-scraped surfaces. Considering the disadvantages and resultant injury in the use of wet tents, it is evident that fumigation should be discontinued as soon as the leaves and fruit become thoroughly moist. The presence of moisture on trees does not appear to reduce the efficacy of hydrocyanic-acid gas against scale insects.

EFFECTS OF FUMIGATION ON UNHEALTHY TREES.

Occasionally a part or all of an orchard is composed of trees weakened by lack of such essential treatments as proper cultivation, fertilization, or irrigation. Many orchards contain trees weakened by attacks of gum disease, scale insects, gophers, and numerous other agents which check their normal development. These unhealthy trees are more susceptible to injury from fumigation than are perfectly healthy ones, and a dosage which in no way would affect a perfectly healthy plant is likely to cause pitting of fruit and shedding of leaves. If this injury is confined to unhealthy trees there is no occasion for alarm, as usually the fruit on such trees is of an inferior grade. Unhealthy leaves would not remain on trees in this condition much longer, and the hastening of their removal is soon followed by a fresh, invigorated growth which in all respects is superior to the old.

INFLUENCE OF SOIL CONDITIONS ON FUMIGATION.

Where the cultivation or irrigation of citrus trees does not receive proper attention during the hot, dry months, as sometimes happens, the soil may become dry and hard, and possibly the plants may suffer from lack of necessary moisture. The question frequently arises as

to the danger of injury in fumigating such trees. In all probability citrus trees fumigated while suffering a *slight* lack of moisture will not show any more injury than those fumigated where necessary moisture is present. Trees allowed to suffer from long-continued lack of moisture, however, become weak and unhealthy, and their treatment with hydrocyanic-acid gas frequently results in severe injury, as would be the case even if such unhealthy trees were under the most ideal moisture conditions at the time of fumigation.

Fumigation with dry tents after a heavy rain when the soil is wet does not appear to affect citrus trees adversely. It is inadvisable, however, to continue field operations on wet soils, more especially wet, sandy soils, as the tents themselves will soon become wet, heavy, and soil-covered, and when in this condition, as explained under "Moisture" (p. 26), they can not be used without danger of injury to the fruit and branches.

STRENGTH OF GAS CITRUS TREES WILL STAND WITHOUT INJURY.

The lemon tree is much more resistant to injury from fumigation than is the orange or grapefruit and seldom suffers appreciable damage when treated under normal conditions with either schedule No. ¾ or schedule No. 1. Some varieties of oranges are injured more easily than others. Of the varieties of commercial importance in California, the Navel and Valencia are the least susceptible to injury from gas treatment. The seedling is almost equally hardy, while the tangerine (mandarin) stands the gas quite well. The Mediterranean Sweet is not quite so resistant to the gas as are the preceding varieties, and the Homosassa and St. Michael are easily injured by fumigation. It is inviting damage to fumigate the last two varieties with schedule No. 1, and injury might result with schedule No. ¾ unless prevailing conditions were favorable. Fortunately, the Navel, the Valencia, and seedlings comprise the bulk of the oranges grown in this State.

In general a strength of gas up to schedule No. ¾ can be used on citrus trees with a minimum amount of injury if care be exercised, although with schedule No. 1 more pitting is to be expected. Unless it is desired to eradicate a resistant pest on a few badly-infested trees, doses exceeding those in schedule No. 1 should not be used while fruit is present, except during the winter, when citrus trees are more or less dormant and the fruit is resistant to gas injury.

As fruit on the tree matures its resistance to gas injury increases. Fruit in transport or in storage appears to be more resistant to gas injury than fruit on the tree.

FUMIGATION INJURY TO SPRAYED TREES.

Orange trees frequently are sprayed for the control of certain insect pests or plant diseases. The sprays in common use are Bordeaux mixture, lime-sulphur solution, and petroleum oils. If trees are fumigated after the application of Bordeaux mixture, injury will result, especially during damp weather. In severe cases all the leaves will fall and much fruit will be spotted. Injury is known to have appeared fully six months after the spraying. Furthermore, fumigation has been observed seriously to injure trees the trunk and branches of which had been painted previously with Bordeaux paste, although the paste did not touch the fruit or foliage. Very little complaint has resulted from the fumigation of trees where the trunks alone received Bordeaux application.

Trees previously treated with an oil or sulphur spray can be fumigated without injury other than that which might occur on unsprayed trees. If the trees are *weakened* by the use of oil sprays, however, fumigation may cause leaf-drop.

FUMIGATION OF TREES IN BLOOM.

Trees may be fumigated while in bloom without unusual injury.

CITRUS INSECTS AND THEIR CONTROL.

CITRUS PESTS AGAINST WHICH ORCHARD FUMIGATION MAY BE PRACTICED.

Fumigation with hydrocyanic-acid gas is especially adapted to the control of scale insects and white flies, which live a part or all of their existence attached to the plants, and, as practiced at the present time, orchard fumigation is confined almost exclusively to the control of this class of insects on citrus fruit trees.

DIRECTIONS FOR CONTROLLING VARIOUS CITRUS PESTS.

Much experimental work with fumigation against various citrus pests in California and Florida has resulted in definite records of the successful control of these insects. Specific information on the control of the common insect pests of citrus trees in this country is given in Table I. Insects such as the white flies and armored scales, which can be destroyed in practically all stages of development, can be fumigated at any time the trees are in a condition best fitted to resist injury. In general, soft or unarmored scales are very resistant to hydrocyanic-acid gas in the mature and egg stages; it is advisable, therefore, to fumigate these pests during their breeding season while the insects are in the immature stages.

TABLE I.—*Control of citrus-fruit insect pests by fumigation with hydrocyanic-acid gas.*

Insect.	Dosage and exposure.		Season for treatment.	
	Schedule No.	Time.	In California.	In Florida.
California red scale (*Chrysomphalus aurantii* Mask.)	¾	45 minutes[1]	August to April	
California yellow scale (*Chrysomphalus citrinus* Coq.)	¾	do	do	
Purple scale (*Lepidosaphes beckii* Newm.)	¾	1 hour	do	December to February
Glover's scale (*Lepidosaphes gloverii* Pack.)	¾	do	do	Do.
Florida red scale (*Chrysomphalus aonidum* L.)	¾	45 minutes		Do.
Black scale (*Saissetia oleae* Bern.):				
Immature insects	¾	do	August to December	
Mature insects	1	1 hour	do	
Citricola scale (*Coccus citricola* Camp.)	¾	45 minutes	July to September	
Citrus white fly (*Dialeurodes citri* Ashm.)	¾	do		Do.
Cloudy-winged white fly (*Dialeurodes citrifolii* Morg.)	¾	do		Do.

[1] At Corona, Riverside County, this insect appears to be more resistant to hydrocyanic-acid gas than elsewhere in California. A stronger dosage than that indicated in the table is required in this region.

LENGTH OF EXPOSURE.

In fumigation with untreated cloth tents practically all of the gas escapes before the expiration of one hour, unless the weather is very damp. Experience in orchard fumigation has shown that an exposure of 45 minutes for most insects gives practically as good results as that of an hour. Where eggs are present, the one-hour exposure results in slightly more effective work.

TIME OF YEAR FOR FUMIGATION.

Many of the scale insects can be destroyed easily by fumigation at any stage of development. These insects may be fumigated at any time of the year, and include such species as the red, yellow, and purple scales. Other scale insects are very resistant to treatment in the egg and adult stages. This type of insect, which includes such species as the black, hemispherical, and soft brown scales, must be treated in the early stages of development, when they are least resistant to the gas.

Unfortunately citrus trees are not in a condition to resist gas injury equally well at all times of the year, and care must be used to see that fumigation is carried on under the most favorable weather conditions and when the fruit is of fair size. It is preferable, of course, to fumigate after the fruit has been picked, but this is seldom possible in California. The most suitable season for orchard treatment in California is from the 1st of August to the middle of December; in the Gulf Coast States, from the 1st of December to the last of February.

REMOVAL OF OLD SCALY FRUIT.

Scale insects on fruit are usually more difficult to destroy than those on the leaves or branches. Especially is this true for an egg-laying species such as the purple scale. When fruit is picked, a few old scaly oranges are occasionally left on the trees. Such fruit should be removed before fumigation, lest it become a source of reinfestation after the other parts of the tree have been cleaned.

SUCCESSIVE TREATMENTS.

As stated, some scale insects are very resistant to fumigation in the egg and adult stages, though easily destroyed in the immature stages. Occasionally plants which will not stand a high concentration of gas are infested with all stages of scale insects, and if the eggs and adults are very resistant it is possible to control the pest through the destruction of the immature insects by using a concentration of gas which will not injure the plants. In such cases successive fumigations are necessary; the first will destroy all the immature insects present at the time of treatment, and fumigations repeated at the necessary intervals will destroy all the insects hatching since the preceding fumigation. This work necessitates a knowledge of the life history of the insect concerned.

COST OF FUMIGATION.

The cost of fumigating an orchard depends primarily on the size of the trees and the dosage rate used. The average citrus orchard in California, where fumigation is practiced, requires an expenditure of from $25 to $40 per acre for one treatment. Large seedling trees are more expensive, while young trees cost considerably less. Estimates given by contract fumigators usually are based on the cost of the two factors, chemicals and tree covering. The present cost of chemicals approximates 30 cents a pound. In commercial work the average price for covering with tents 45 feet or less in diameter is from 10 to 12 cents per tree. The cost of thirty 45-foot tents of special 8-ounce fumigating duck, together with the other equipment necessary to complete the outfit, will approximate $1,500.

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Preparations for Winter Fumigation for Citrus White Fly. (Entomology Circular 111.)

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FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

The Mediterranean Fruit Fly in Hawaii. (Department Bulletin 536.) Price, 30 cents.

Mango Weevil. (Entomology Circular 141.) 1911. Price, 5 cents.

Fumigation for Citrus White Fly, as Adapted to Florida Conditions. (Entomology Bulletin 76.) 1908. Price, 15 cents.

Fumigation Investigations in California. (Entomology Bulletin 79.) 1909. Price, 15 cents.

Hydrocyanic-acid Gas Fumigation in California. (Entomology Bulletin 90, 3 pts.) 1913. Price, 20 cents.

Fumigation of Citrus Trees. (Entomology Bulletin 90, Pt. I.) 1913. Price, 20 cents.

Value of Sodium Cyanid for Fumigation Purposes. (Entomology Bulletin 90, Pt. II.) 1913. Price, 5 cents.

Chemistry of Fumigation with Hydrocyanic-acid Gas. (Entomology Bulletin 90, Pt. III.) 1913. Price, 5 cents.

White Flies Injurious to Citrus in Florida. (Entomology Bulletin 92.) 1911. Price, 25 cents.

Orange Thrips, Report of Progress. (Entomology Bulletin 99, Pt. I.) 1911. Price, 5 cents.

Red-banded Thrips. (Entomology Bulletin 99, Pt. II.) 1912. Price, 5 cents.

Natural Control of White Flies in Florida. (Entomology Bulletin 102.) 1912. Price, 20 cents.

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